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ABSTRACT

This study explores the mathematics-related beliefs of Flemish junior high school students and how they relate to gender, achievement level, and tracking level. Results indicate that students' mathematics-related belief systems are interconnected very strongly with the educational track in which they take their mathematics courses, but also with gender and the way the teacher evaluates their achievement level. (KHR)

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'WHEN GIRLS VALUE MATHEMATICS AS HIGHLY AS BOYS': AN ANALYSIS OF JUNIOR-HIGH STUDENTS' MATHEMATICS-RELATED BELIEFS

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Introduction

Recent theories on cognition and learning (e.g., Greeno, Collins, & Resnick, 1996; Salomon & Perkins, 1998) point to the socio-historical embeddedness and the constructive nature of thinking and problem solving. From such a perspective, learning is primarily defined as a form of engagement that implies the active use of a well developed body of cognitive and metacognitive knowledge and strategies but cannot be reduced to it. Next to these cognitive aptitudes, conative and affective aptitudes are considered equally influential factors constituting students' learning and problem solving. On a conceptual level researchers in the field of mathematics learning try to capture this interrelated influence of (meta)cognitive, conative and affective factors on mathematical learning and problem solving in the notion of a "mathematical disposition". Such a disposition refers to the integrated mastery of five categories of aptitude (De Corte, Verschaffel, & Op 't Eynde, 2000):

1. A well-organized and flexibly accessible knowledge base involving the facts, symbols, algorithms, concepts, and rules that constitute the contents of mathematics as a subject-matter field.
2. Heuristics methods, i.e. search strategies for problem solving which do not guarantee, but significantly increase the probability of finding the correct solution because they induce a systematic approach to the task.
3. Meta-knowledge, which involves knowledge about one's cognitive functioning (metacognitive knowledge), on the one hand, and knowledge about one's motivation and emotions that can be used to deliberately improve motivational and volitional efficiency (metavolitional knowledge), on the other hand.
4. Mathematics-related beliefs, which include the implicitly and explicitly held subjective conceptions about mathematics education, the self as a mathematician, and the social context, i.e. the class-context.
5. Self-regulatory skills, which embrace skills relating to the self-regulation of one's cognitive processes (metacognitive skills or cognitive self-regulation), on the one hand, and of one's volitional processes (metavolitional skills or volitional self-regulation), on the other hand.

Acquiring such a mathematical disposition is a condition for students to become competent problem solvers, equipped to recognize and tackle mathematical problems in different contexts. It has become the goal of mathematics education (NCTM, 2000). Students' mathematics-related beliefs as a central component of a mathematical disposition are thought to have a strong impact on students' learning and problem solving in mathematics. In his pioneering work on students' mathematics beliefs Schoenfeld (1985) pointed out that

> Belief systems are one's mathematical world view, the perspective with which one approaches mathematics and mathematical tasks. One's beliefs about mathematics can determine how one chooses to approach a problem, which techniques will be used or avoided, how long and how hard one will work on it, and so on. Beliefs establish the context within which resources, heuristics, and control operate. (p.45)

Nowadays, there is a growing body of research that supports these claims and shows how students' beliefs influence their mathematical learning and problem solving. A wide variety of beliefs have been studied such as beliefs about mathematics (e.g., Lampert, 1990), epistemological beliefs (e.g., Schommer, Crouse, & Rhodes, 1992), motivational beliefs related to mathematics (e.g., Kloosterman & Cougan, 1994), beliefs about mathematics teaching (e.g., Boaler, 1997), etc. Typically these beliefs have been studied in an isolated way. Rarely scholars have investigated these different beliefs in relation to each other analyzing the functioning of students' belief *systems* rather than just one specific category of beliefs. Moreover, there is no consensus on what precisely the different categories of beliefs are that play a role in mathematics learning and problem solving (Op 't Eynde, De Corte, &

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Verschaffel, 2002). So far, a coherent theoretical framework that identifies the different categories of students' beliefs in relation to each other is lacking.

In a recent study we have tried to develop such a framework and were able to identify the major categories of students' beliefs that constitute their mathematics-related belief system. We found four major categories (see Op 't Eynde & De Corte, 2003):

(1) Beliefs about the role and the functioning of their own teacher
(2) Beliefs about the significance of and their own competence in mathematics
(3) Mathematics as a social activity
(4) Mathematics as a domain of excellence

These categories were found to be closely related in different ways. The correlations between the different factors indicate that students holding a more social, dynamic view of mathematics (Factor 3) attach more value to mathematics and have more confidence in their mathematical capacities (Factor 2). Moreover, they also tend to have more positive beliefs about the teacher and his functioning in class (Factor 1). Students holding positive beliefs about their teacher also consider mathematics more valuable and feel more confident about it. Rather surprising, was the low correlation we found between Factors 3 and 4 which implies that both views of mathematics are not very strongly related to each other, implying that they can not be treated as the opposite poles of one dimension.

The identification of these categories that constitute students' mathematics-related belief systems is a necessary first step to further unravel the role of students' beliefs in mathematics learning. However, if we want to fully understand the nature and the functioning of students' beliefs thoroughly we should not only identify the different categories of beliefs and their relations with each other, but also investigate how they relate to other student characteristics as well as to characteristics of the social contexts.. After all, students' beliefs are in many ways determined by the broad socio-historical context they live and work in. Participating in classroom activities they develop beliefs about issues related to it (e.g., learning, mathematics, teaching, etc) in close interaction with their prior knowledge and beliefs which themselves are the result of students' participation in former classrooms and/or other contexts (Op 't Eynde, De Corte, & Verschaffel, 2002).
Students' beliefs are the exponents of a reflexive relation between the context and the individual, between the social and the personal (see Cobb & Bowers, 1999). Really understanding what students believe implies situating these beliefs within the relevant personal and socio-historical context, i.e. analyzing the relations with other student and context characteristics. Not only will this result in a deeper understanding of the beliefs students hold, it also might clarify some of its origins and as such point to issues and mechanisms that should be addressed if we want to change students' beliefs.

Research question
Having identified the different categories of students' mathematics-related belief systems, we now can proceed to further unravel what students actually believe. As already mentioned above fully understanding what they believe in relation to mathematics necessitates an analysis not only of the respective categories of beliefs but also of the relations of these beliefs with other student and context characteristics. In this second study we therefore looked for an answer on the following research question:

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What are the mathematics-related beliefs of Flemish junior high students and how do they relate to gender, achievement level, and track level?

Subjects and methodology

Taking into account that in an earlier study (see Op 't Eynde & De Corte, 2003) we were able to develop a questionnaire - the Mathematics-Related Beliefs Questionnaire [MRBQ] – that was shown to be a reliable measure of students mathematics-related beliefs, we decided to further investigate the data of this study. The data consisted of the belief scores of 365 students of Flemish junior high school (age 14). Students came from 21 classrooms spanning the different tracks that can be followed in the second year of secondary education. Although the core subject-matter domains, including mathematics, are the same for everyone, students choose optional subjects that can be either vocational oriented (technical courses), humanities oriented (courses in humanities), and/or classical oriented (Latin/Greek courses). Generally speaking, the choice of optional subjects is not neutral, but related to the intellectual level of the students. Moreover, the optional subjects taken by the students are used in most schools as a grouping criterion for classes, resulting in relatively homogeneous class groups. In our sample 109 students were vocational oriented (low intellectual level), 119 students took humanities courses as optional subjects (moderate intellectual level) and 137 students were classical oriented (high intellectual level).

Data analysis

First, we looked for a description of the beliefs students hold by analyzing the means and standard deviations of the respective factors. Second, to examine the relation between, on the one hand, gender, track level, and achievement level (as evaluated by the teacher) and, on the other hand, the respective beliefs students hold, we carried out a 3 (achievement level) X 3 (track level) X 2 (gender) multivariate analysis of variance (MANOVA) using the four mathematics-related belief factors as dependent variables. Although all three independent variables are measured at student level and strictly speaking can be seen as student characteristics, "track level" in many ways is a context characteristic (see above) and will be interpreted as such in this study.

Results

In general, Flemish junior high students have a rather dynamic view of mathematics (M F3= 3.70)[1]. They do not perceive mathematics primarily as a subject in which they want to prove themselves better than others (M F4= 2.12). Somewhat surprising, most students consider mathematics a rather valuable, interesting subject and feel pretty confident about their capacities in mathematics (M F2= 3.11). They are fairly satisfied with the way their teacher gives mathematics and interacts with them in the mathematics class (M F1= 2.82). They think that at most occasions (s)he explains the subject matter well, is motivating and cares about how they feel in class. Clearly, not every one of them shares the same opinion and holds the same beliefs to the same extent. The variance analyses point to important differences between groups of students depending on the track level they are in, their gender, and their achievement level.

We found a significant multivariate main effect for track level $F(8, 688) = 6.40$, $p < 0.0001$, for gender $F(4, 344) = 4.46$, $p < 0.01$, and for achievement level $F(8, 688) = 15.95$, $p < 0.0001$, but no significant interaction effects between these variables. This seems to imply that all the independent variables individually relate to students mathematics-related belief

[1] All means refer tot the scores on the original 5-point scale

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systems, but not in any systematic way in interaction with each other, at least not as far as the belief system as a whole is concerned. To analyze in more detail the relevance of track level, gender and achievement level for specific student beliefs we carried out univariate analyses with the respective beliefs as dependent variable.

The results indicate that the higher the track level students are in the more they think of mathematics as a dynamic discipline (F3). Students in the humanities and classical oriented tracks hold this view significantly more ($p < 0.01$) than students in vocational oriented tracks. There is also a significant relation between students' track level and the degree to which they consider (F4) mathematics as a domain of excellence ($p < 0.01$). Students in vocational tracks seem to be more competitive and more regularly perceive mathematics as a subject in which one can proof oneself better than others. Gender also is not irrelevant here. In general, boys clearly consider mathematics much more a domain of excellence than girls ($p < 0.001$)
Students in higher track levels are also more convinced of the relevance of and their competence in mathematics (F2). There is, however, an interesting interaction effect with gender here ($p < 0.05$). Girls tend to have more positive beliefs than boys in the classical and vocational tracks but in the humanities track boys attach more value to mathematics and are more confident than girls. Not surprisingly, the results also indicate that high achieving students have more positive beliefs about the relevance of and their competence in mathematics than low achieving students ($p < 0.0001$). Also here we found a tendency towards an interaction effect with gender ($p < 0.053$), pointing to the fact that given an equal achievement level boys tend to attach more value to mathematics than girls and are more confident about their capacities, except for the moderate achievers. There, girls have higher scores on factor 2 than boys.
Last but not least, the higher the track level the more positive beliefs (F1) students have about their teacher ($p < 0.05$). Students in more general education tracks (i.e. humanities and classical) are more satisfied with the way their teacher behaves than students in vocational tracks. Girls also tend to hold more positive beliefs about their teacher than boys, except for the classical track. An analysis of the intra-class correlations to investigate the relative impact of specific classgroup characteristics compared to the more general track characteristics (included as an independent variable in the study) and individual student characteristics (of which some are included as an independent variable), shows that students' beliefs about the functioning and the role of their own teacher are much more situated in the specific class context than the other mathematics-related beliefs. We found an intra-class correlation of 0.46 for factor 1 compared to 0.24 (F2), 0.14 (F3), 0.13 (F4).

Conclusions and discussion
The results of this study clearly indicate that students' mathematics-related belief systems are interconnected very strongly with the educational track in which they take their mathematics course, but also with gender and the way the teacher evaluates their achievement level. Notwithstanding their respective relations to students' belief systems as a whole, it is clear that each of these independent variables is more closely linked to some categories of beliefs than to others.

However, students' track level appears to be significantly related to all four factors. On the one hand, this result certainly substantiates the influence of the social context on students' belief systems. Track level can be interpreted as a composite variable that includes a variety of classroom and other characteristics such as the actual content of the mathematics classes (the level of difficulty aimed at), the teaching style, class grouping, disciplinary problems, parents expectations, etc. On the other hand, one cannot ignore the fact that the choice of

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optional subjects (i.e. tracks) is not neutral but in many cases related to the intellectual level of the students. This might imply that the relevance of track level for students' belief systems refers as much to a relation between students' intellectual level and their beliefs as to a close connection between beliefs and the social context.

Very relevant from a mathematics education perspective are also the relations found between gender and students' belief systems. Especially, the interaction between gender and track level is highly interesting. Indeed, we found that in two of the three tracks girls value mathematics more and have more confidence in their capacities than boys. This is quite surprising when we look at the international literature of the past decades. There, gender differences disfavoring girls are found especially regarding students' efficacy and value beliefs for mathematics at the junior-high level
For instance, Fennema & Sherman (1978) found that

> when sex-related differences in mathematics learning in favor of males were found, sex-related differences in favor of males were also found in six affective variables: mathematics confidence, stereotyping mathematics as a male domain, attitude toward success, perceptions of mothers' and fathers' attitudes toward them as learners of mathematics, and usefulness of mathematics. (p. 198)

In general, these early findings were confirmed in more recent studies (e.g., Fennema, 1996; Leder, 1992; Meece, Wigfield, & Eccles, 1990) and in large-scale international comparative surveys (e.g., TIMMS, 1999). These gender differences are still not very well understood neither in their origins nor in their developmental aspects. Recently, scholars have been reporting data that substantiate the opposite phenomenon (e.g., Leder, 2001). Boys were found to perform worse than girls and to hold more negative beliefs about mathematics. They seem to become the problem although this is certainly not the case in every country (e.g., Greece). Based on our study and other more large-scale studies (see e.g., Van Damme, Van Landeghem, De Fraine, Opdenakker, & Onghena, 2000) girls certainly seem to do better than boys in Flemish junior high schools. Although, clearly girls did not have more positive beliefs than boys in every track. In humanities boys had significantly more positive beliefs about the self than girls. This indicates that the relationship between beliefs, gender and context is a rather complex one and supports the hypothesis formulated by some of these researchers that socio-historical and socio-cultural factors, as well as very specific social context factors, play an important role in the development and influence of students' beliefs, rather than sex as such.

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